US006061456A

United States Patent [19]

Andrea et al.

[11] Patent Number: 6,061,456

[45] Date of Patent: *May 9, 2000

[54] NOISE CANCELLATION APPARATUS

[75] Inventors: **Douglas Andrea**, Old Brookville; **Martin Topf**, Brooklyn, both of N.Y.

[73] Assignee: **Andrea Electronics Corporation**, Melville, N.Y.

[*] Notice: This patent is subject to a terminal disclaimer.

[21] Appl. No.: **09/089,710**

[22] Filed: **Jun. 3, 1998**

Related U.S. Application Data

[62] Division of application No. 08/912,459, Aug. 18, 1997, which is a division of application No. 08/485,047, Jun. 7, 1995, Pat. No. 5,732,143, which is a continuation-in-part of application No. 08/339,126, Nov. 14, 1994, Pat. No. 5,673,325, which is a continuation-in-part of application No. 07/968,180, Oct. 29, 1992, Pat. No. 5,381,473.

[51] **Int. Cl.**[7] **G10K 11/16**

[52] **U.S. Cl.** **381/71.6**; 381/71.13; 381/71.7

[58] **Field of Search** 381/71.6, 71.13, 381/72, 94.7, 71.7, 93, 74, 372, 386

[56] **References Cited**

U.S. PATENT DOCUMENTS

Re. 34,236	4/1993	Taylor .
D. 344,730	3/1994	Gattey et al. .
2,379,514	7/1945	Fisher .

(List continued on next page.)

FOREIGN PATENT DOCUMENTS

0 380 290 A2	8/1990	European Pat. Off. .
0390386	10/1990	European Pat. Off. .
0 509 742 A2	10/1992	European Pat. Off. .

OTHER PUBLICATIONS

Samuel Kerem, "Dual Microphones Separate Voice From Noiise", Electrical Design News, Jun. 23, 1994.

Rabiner et al., IEEE Trans. on Acous, vol. ASSP–24, No. 5, Oct. 1976, pp. 399–418

Youla et al., IEEE Trans on Acous., vol. MI–1, No. 2, Oct, 1982, pp. 81–101.

(List continued on next page.)

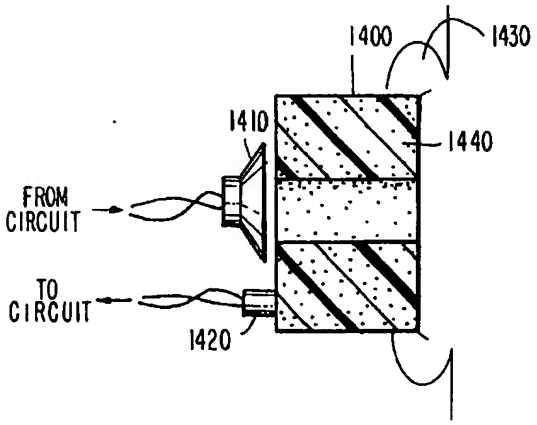
Primary Examiner—Vivian Chang

Attorney, Agent, or Firm—Frommer Lawrence & Haug, LLP; Thomas J. Kowalski

[57] **ABSTRACT**

Disclosed is a transducer for use in a noise cancellation apparatus for reducing background noise. The transducer includes a housing having first microphone means for receiving a first acoustic sound composed of speech originating from an operator operating the apparatus and background noise, and for converting the first acoustic sound to a first signal, and second microphone means arranged at a predetermined angle ϕ in close proximity with respect to the first microphone means for receiving a second acoustic sound composed of substantially the background noise and for converting the second acoustic sound to a second signal. The first and second microphones are connected to a differential amplifier means of the noise cancellation apparatus so as to obtain a signal representing substantially speech. The amplifier means is for receiving acoustic sounds from each microphone and has a first terminal and a second terminal, wherein the second terminal is grounded. The transducer further includes a transistor means for receiving and amplifying an AC signal representative of the audio input from each microphone; and means for filtering the amplified AC signal from the DC signal, so that the DC signal powers the amplifier means. Also disclosed is a method for calibrating an active noise reduction apparatus including a housing having a speaker to produce an acoustic anti-noise signal in the housing, a microphone to detect an external noise signal, and an amplitude adjustment means to calibrate the acoustic anti-noise signal to create a quiet zone in the housing for operation with an independent electrical assembly, wherein the apparatus is calibrated separately from the electrical assembly. The method includes the steps of: inputting the external noise signal received by the microphone to produce an anti-noise signal; transmitting to the speaker the anti-noise signal having an equal gain and opposite phase response to the external noise signal detected by the microphone; and balancing the gain and phase response of the anti-noise signal by the amplitude adjustment means located in the noise reduction apparatus to match the gain and phase response of the external noise signal to yield a theoretical zero in the quiet zone.

23 Claims, 30 Drawing Sheets



U.S. PATENT DOCUMENTS

2,972,018	2/1961	Hawley et al. .
3,098,121	7/1963	Wadsworth .
3,101,744	8/1963	Warnaka .
3,170,046	2/1965	Leale .
3,247,925	4/1966	Warnaka .
3,262,521	7/1966	Warnaka .
3,298,457	1/1967	Warnaka .
3,330,376	7/1967	Warnaka .
3,394,226	7/1968	Andrews, Jr. .
3,416,782	12/1968	Warnaka .
3,422,921	1/1969	Warnaka .
3,562,089	2/1971	Warnaka et al. .
3,702,644	11/1972	Fowler et al. .
3,830,988	8/1974	Mol et al. .
3,889,059	6/1975	Thompson et al. .
3,890,474	6/1975	Glicksberg .
4,068,092	1/1978	Ikoma et al. .
4,122,303	10/1978	Chaplin et al. .
4,153,815	5/1979	Chaplin et al. .
4,169,257	9/1979	Smith .
4,241,805	12/1980	Chance, Jr. .
4,243,117	1/1981	Warnaka .
4,261,708	4/1981	Gallagher .
4,321,970	3/1982	Thigpen .
4,334,740	6/1982	Wray .
4,339,018	7/1982	Warnaka .
4,417,098	11/1983	Chaplin et al. .
4,433,435	2/1984	David .
4,453,600	6/1984	Thigpen .
4,455,675	6/1984	Bose et al. .
4,461,025	7/1984	Franklin .
4,463,222	7/1984	Poradowski .
4,473,906	9/1984	Warnaka et al. .
4,477,505	10/1984	Warnaka .
4,489,441	12/1984	Chaplin et al. .
4,490,841	12/1984	Chaplin et al. .
4,494,074	1/1985	Bose .
4,527,282	7/1985	Chaplin et al. .
4,530,304	7/1985	Gandos .
4,539,708	9/1985	Norris .
4,562,589	12/1985	Warnaka et al. .
4,566,118	1/1986	Chaplin et al. .
4,570,155	2/1986	Skarman et al. .
4,589,136	5/1986	Poldy et al. .
4,589,137	5/1986	Miller .
4,600,863	7/1986	Chaplin et al. .
4,630,302	12/1986	Kryter .
4,630,304	12/1986	Borth et al. .
4,636,586	1/1987	Schiff .
4,649,505	3/1987	Zinser, Jr. et al. .
4,653,102	3/1987	Hansen .
4,654,871	3/1987	Chaplin et al. .
4,672,674	6/1987	Clough et al. .
4,683,010	7/1987	Hartmann .
4,736,432	4/1988	Cantrell .
4,752,961	6/1988	Kahn .
4,771,472	9/1988	Williams, III et al. .
4,783,798	11/1988	Leibholz et al. .
4,783,817	11/1988	Hamada et al. .
4,783,818	11/1988	Graupe et al. .
4,791,672	12/1988	Nunley et al. .
4,811,404	3/1989	Vilmur et al. .
4,833,719	5/1989	Carme et al. .
4,837,832	6/1989	Fanshel .
4,847,897	7/1989	Means .
4,862,506	8/1989	Landgarten et al. .
4,878,188	10/1989	Ziegler et al. .
4,908,855	3/1990	Ohga et al. .
4,928,307	5/1990	Lynn .
4,930,156	5/1990	Norris .
4,947,356	8/1990	Elliott et al. .
4,951,954	8/1990	MacNeill .
4,955,055	9/1990	Fujisaki et al. .
4,959,865	9/1990	Stettiner et al. .
4,963,071	10/1990	Larwin et al. .
4,977,600	12/1990	Ziegler .
4,985,925	1/1991	Langberg et al. .
4,991,433	2/1991	Warnaka et al. .
5,001,763	3/1991	Moseley .
5,010,576	4/1991	Hill .
5,018,202	5/1991	Takahashi et al. .
5,023,002	6/1991	Schweizer et al. .
5,029,218	7/1991	Nagayasu .
5,046,103	9/1991	Warnaka et al. .
5,052,510	10/1991	Gossman .
5,070,527	12/1991	Lynn .
5,091,954	2/1992	Sasaki et al. .
5,097,923	3/1992	Ziegler et al. .
5,105,377	4/1992	Ziegler, Jr. .
5,117,461	5/1992	Moseley .
5,121,426	6/1992	Bavmhauer .
5,125,032	6/1992	Meister et al. .
5,126,681	6/1992	Ziegler, Jr. et al. .
5,133,017	7/1992	Cain et al. .
5,134,659	7/1992	Moseley .
5,138,663	8/1992	Moseley .
5,138,664	8/1992	Kimura et al. .
5,209,326	5/1993	Harper .
5,219,037	6/1993	Smith et al. .
5,226,077	7/1993	Lynn et al. .
5,226,087	7/1993	Ono .
5,251,263	10/1993	Andrea et al. .
5,251,863	10/1993	Gossman et al. .
5,260,997	11/1993	Gattey et al. .
5,272,286	12/1993	Cain et al. .
5,276,740	1/1994	Inanaga et al. .
5,311,446	5/1994	Ross et al. .
5,311,453	5/1994	Denenberg et al. .
5,313,945	5/1994	Friedlander .
5,315,661	5/1994	Gossman et al. .
5,327,506	7/1994	Stites, III .
5,332,203	7/1994	Gossman et al. .
5,348,124	9/1994	Harper .
5,353,347	10/1994	Irissou et al. .
5,361,303	11/1994	Eatwell .
5,365,594	11/1994	Ross et al. .
5,375,174	12/1994	Denenberg .
5,381,473	1/1995	Andrea et al. .
5,381,481	1/1995	Gammie et al. .
5,384,843	1/1995	Masuda et al. .
5,402,497	3/1995	Nishimoto et al. .
5,414,769	5/1995	Gattey et al. .
5,414,775	5/1995	Scribner et al. .
5,416,845	5/1995	Shen .
5,418,857	5/1995	Eatwell .
5,423,523	6/1995	Gossman et al. .
5,431,008	7/1995	Ross et al. .
5,434,925	7/1995	Nadim .
5,440,642	8/1995	Denenberg et al. .
5,448,637	9/1995	Yamaguchi et al. .
5,452,361	9/1995	Jones .
5,457,749	10/1995	Cain et al. .
5,469,087	11/1995	Eatwell .
5,471,106	11/1995	Curtis et al. .
5,471,538	11/1995	Sasaki et al. .
5,473,214	12/1995	Hildebrand .
5,475,761	12/1995	Eatwell .
5,481,615	1/1996	Eatwell et al. .
5,493,615	2/1996	Burke et al. .
5,502,869	4/1996	Smith et al. .
5,511,127	4/1996	Warnaka .
5,526,432	6/1996	Denenberg .

5,546,467	8/1996	Denenberg .
5,550,334	8/1996	Langley .
5,553,153	9/1996	Eatwell .
5,563,817	10/1996	Ziegler, Jr. et al. .
5,568,557	10/1996	Ross et al. .
5,600,106	2/1997	Langley .
5,604,813	2/1997	Evans et al. .
5,617,479	4/1997	Hildebrand et al. .
5,619,020	4/1997	Jones et al. .
5,621,656	4/1997	Langley .
5,627,746	5/1997	Ziegler, Jr. et al. .
5,638,022	6/1997	Eatwell .
5,638,454	6/1997	Jones et al. .
5,638,456	6/1997	Conley et al. .
5,649,018	7/1997	Gifford et al. .
5,652,770	7/1997	Eatwell .
5,652,799	7/1997	Ross et al. .
5,676,353	10/1997	Jones et al. .
5,692,053	11/1997	Fuller et al. .
5,692,054	11/1997	Parrella et al. .
5,699,436	12/1997	Claybaugh et al. .
5,719,945	2/1998	Fuller et al. .
5,732,143	3/1998	Andrea et al. .
5,745,581	4/1998	Eatwell et al. .
5,748,749	5/1998	Miller et al. .
5,768,473	6/1998	Eatwell et al. .
5,812,682	9/1998	Ross et al. .
5,815,582	9/1998	Claybaugh et al. .
5,828,768	10/1998	Eatwell et al. .
5,835,608	11/1998	Warnaka et al. .
5,838,805	11/1998	Warnaka et al. .

FOREIGN PATENT DOCUMENTS

0 583 900 A1	2/1994	European Pat. Off. .
0 595 457 A1	5/1994	European Pat. Off. .
2305909	10/1976	France .
26 40 324 A1	3/1978	Germany .
3719963	3/1988	Germany .
4008595	9/1991	Germany .
56-89194	7/1981	Japan .
59-64994	4/1984	Japan .
62-189898	8/1987	Japan .
1314098	12/1989	Japan .
0070152	3/1990	Japan .
3169199	7/1991	Japan .
3231599	10/1991	Japan .
1160431	8/1969	United Kingdom .
1289993	9/1972	United Kingdom .
1378294	12/1974	United Kingdom .
2 172 769	9/1986	United Kingdom .
2 289 593	11/1995	United Kingdom .
9205538	4/1992	WIPO .
9217019	10/1992	WIPO .
WO 95/08906	3/1995	WIPO .
WO 96/15541	5/1996	WIPO .

OTHER PUBLICATIONS

Luenberger, Optimization by Vector Space Method, pp. 134–138, No Date supplied.

Sapontis, Probability, Lambda Variables and Structural Processes, pp. 467–474. No Date supplied.

Kuo, Automatic Control of Systems, pp. 504–585, No Date supplied.

Ogata, Modern COntrol Engineering, pp. 474–508, No Date supplied.

Widrow et al., Proceedings of the IEEE, vol. 55, No. 12, Dec. 1967, pp. 2143–2159.

Widrow et al., Proceedings of the IEEE, vol. 63, No. 12, Dec. 1975, pp. 1692–1716.

Beranek, Acoutics, American Institute of Physics, 1986, pp. 116–135. (no month data supplied).

Rubiner et al., Digital Processing of Speech Signals, Prentice Hall, 1978, pp. 130–135. (no month supplied).

White, Moving–Coil Earphone Design, 1963, pp. 188–194. (no month supplied).

Boll. IEEE Trans. on Acous., vol. ASSP–17, No. 2, Apr. 1979, pp. 113–120.

Active Noise and Vibration Technologies, "Open Back Active Noise Cancelling Headset", 1992 (no month supplied).

Active Noise and Vibration Technologies, "New ANVT 100™ Active Headset Reduces Noise While Making Active Technology Affordable to the Consumer Market", Press Release, Aug. 19, 1993.

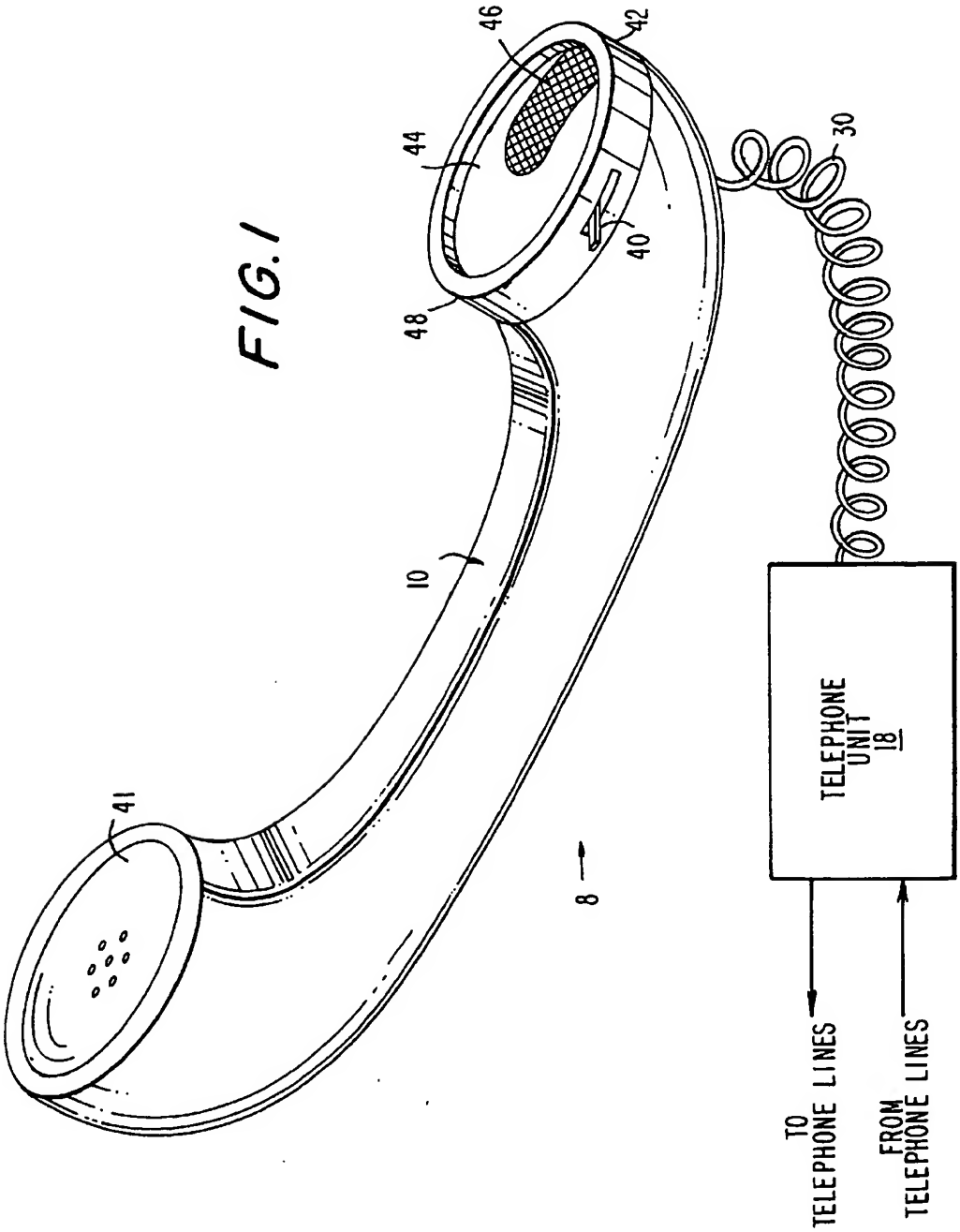
Edward J. Foster, "Switched on Silence", Popular Science, p. 33, 1994 (no month supplied).

Daniel Sweeney, "Sound Conditioning Through DSP", The Equipment Authority, 1994 (no month supplied).

ANVT's NQ100 Advertisement, undated.

NQ100 Advertisement, Sky Mall catalog, undated.

FIG. 1


46
42
44
30
40
48
10
41
8
TELEPHONE UNIT 18
TO TELEPHONE LINES
FROM TELEPHONE LINES

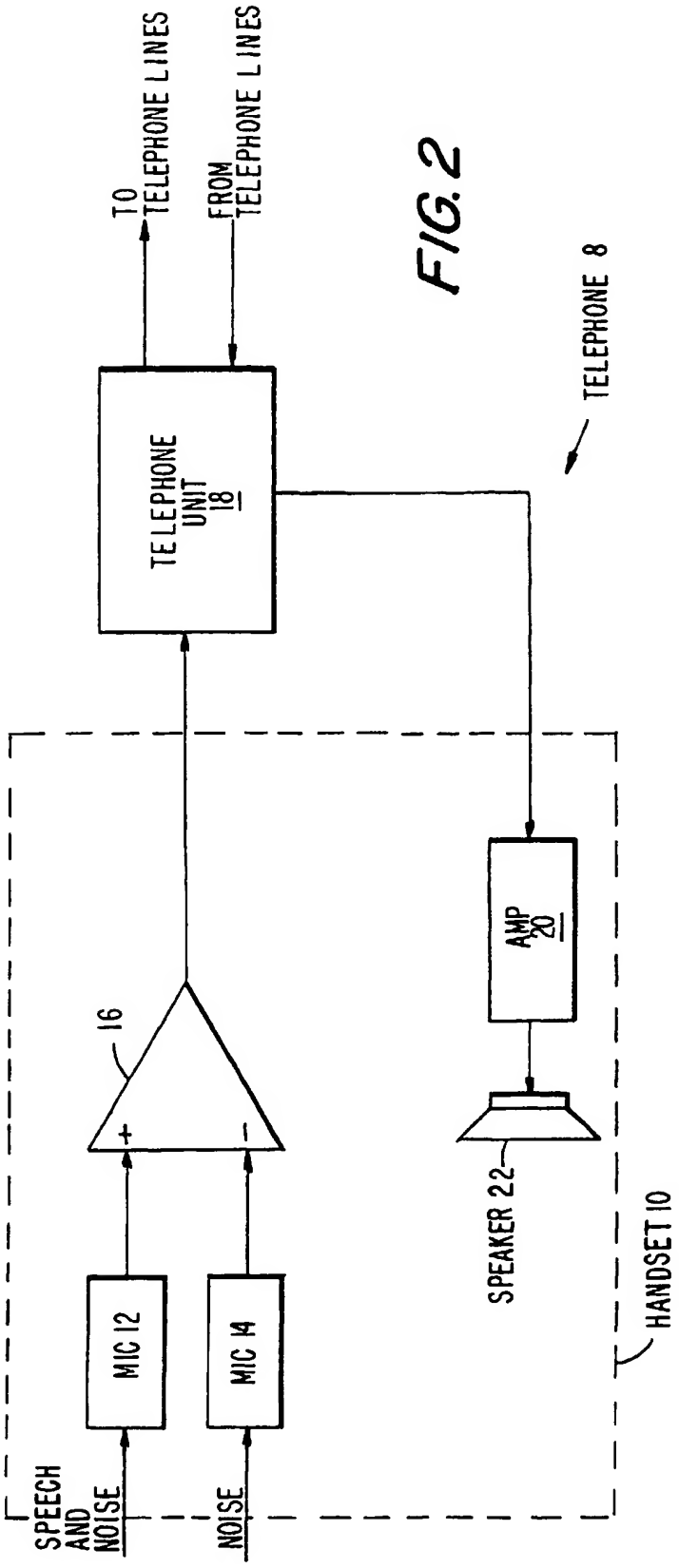

TO TELEPHONE LINES
FROM TELEPHONE LINES
TELEPHONE 8
TELEPHONE UNIT 18
AMP 20
16
+
-
SPEAKER 22
HANDSET 10
MIC 12
MIC 14
SPEECH AND NOISE
NOISE

FIG. 2